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(56) Documents Cited
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EP 0091087 A1
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(54) Abstract Title
Water leak detector

(57) A simple device is proposed for determining the presence of a leak in a water pipe. It is based on the wide-band detection and electronic amplification and processing of the sonic and ultrasonic emissions made by leaking water through a small hole or crack. The device has a widebandwidth and high sensitivity due to the novel coupling 2, 4 to the pipe 1, the design of a metal sounding box 5 for mechanical amplification and the use of an eliptical piezoelectric monomorph 3 as a transduction element. Electronic amplification is frequency dependent in order to provide compensation for the intensity/frequency relationship of the acoustic emissions and the influence of pressure on the sound generated. The device is easy to operate and has settings only for changes in pipe material.

Figure 1.

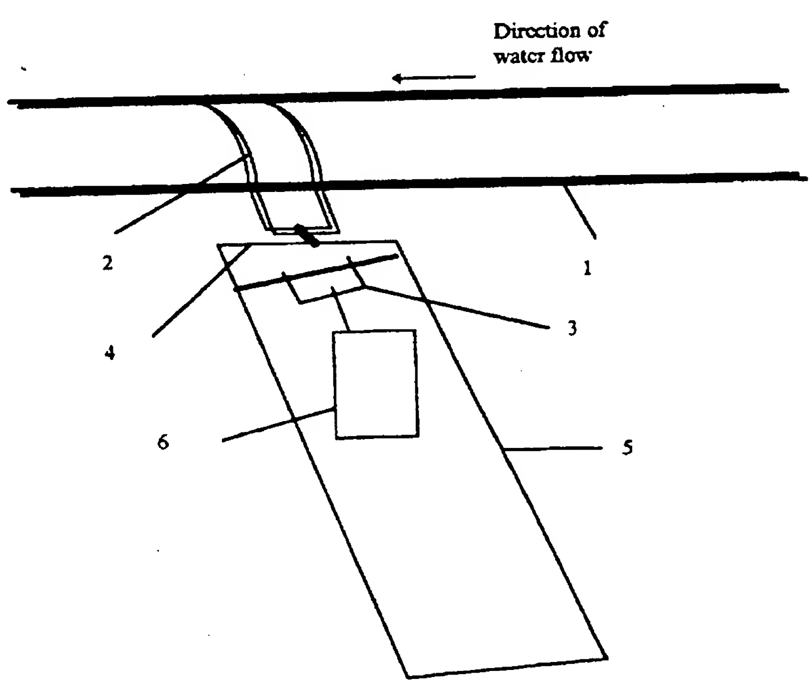

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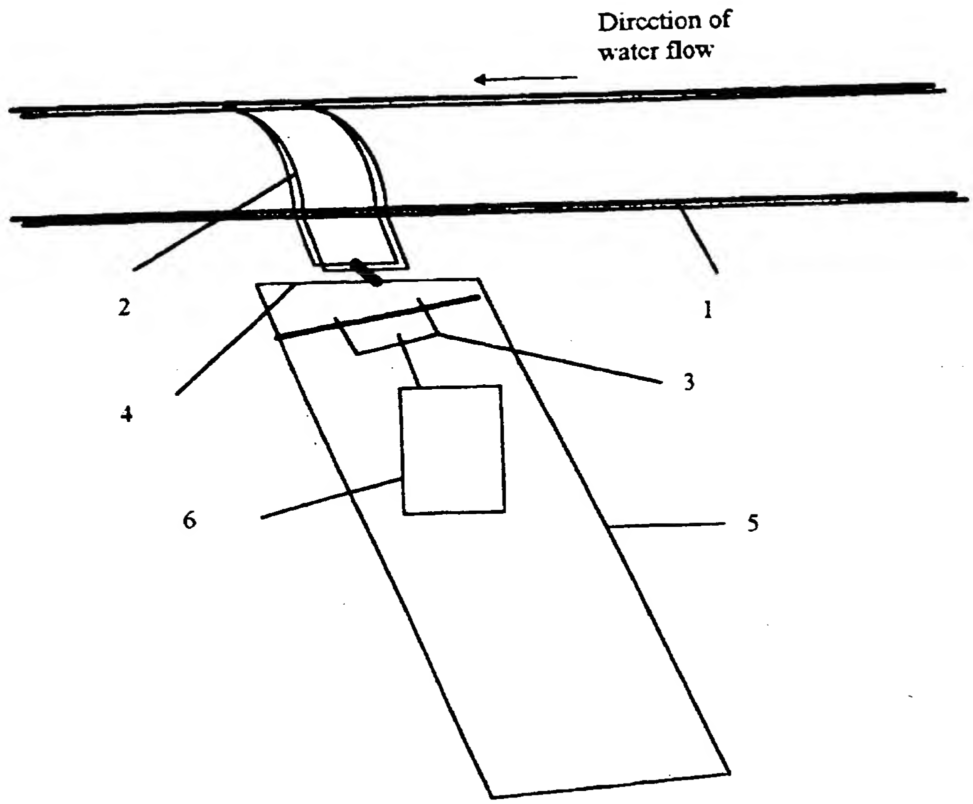
Figure 1.



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Background to the Invention

It has been estimated that as much as 25% of the water consumed in the UK by domestic customers does not actually enter the home. Rather, it is lost through faulty valves, stop-cocks and pipes between the reservoirs and the market. Although this primarily appears as a loss to Water Companies, its effect in times of drought, is to reduce the amount of water available for use by customers. This can result in rationing and general restrictions in the use of water and, ultimately, higher charges to the consumer.

It is accepted that the repairing and renewal of old pipes must become a priority for water company. Generally, they are obliged to seek such leaks at their own expense. However, when the leak occurs on the property of the consumer, and particularly between a water meter and a household stop-cock, the responsibility for detecting the leak becomes less clear. Indeed, the lost water is now charged to the consumer whose property may also be damaged through the effects of the leak. This could result in the weakening of footpaths and roads, and even in subsidence as foundations and walls are compromised. In the home, it can give rise to damp.

Consequently, there is a need for a simple device which can detect leaks and which can provide a householder with an indication of water loss. Although a monitor of water flow at all times may be desirable, in practice, it may be quite unnecessary because the majority of leaks do not simply form as a function of time. Rather, they are already present due to some past event, or they will appear as a result of future activity such as the work of building contractors, earthquake or the passing of a particularly heavy vehicle such as a steam roller.

Thus, the required system should be capable of providing an instant indication of a leak at any time and, in particular, irrespective of the pressure of the mains. The present invention fulfils these criteria and is designed for operation within the home by an unskilled householder. Furthermore, its simplicity enables the device to be applied to a pipe and then removed again quickly and without any special tools. It is anticipated that the device may be used regularly on, perhaps, an annual basis to ensure that there have been no new leaks formed. In the event of a leak it may be used to monitor the approximate position of the leak through feedback and a changing output.

Description of the Invention

Figure 1 shows a schematic drawing of the leak detector. In this drawing, the pipe is labelled 1. The detector is attached momentarily onto the pipe using a metal clip of the type used to hold pipes in position running along walls, labelled 2. This provides good acoustic coupling to the surface of the pipe along which acoustic emissions produced by leaking water will travel. Pipe materials, especially copper, are an excellent medium for supporting the transmission modes of waves such as sound. Consequently, they may travel hundreds of yards along a pipe with only limited attenuation provided that the frequencies are supported without interference by the pipe structure which may then act as an acoustic waveguide in channelling the acoustic energy unidirectionally.

Two different modes may be relevant, longitudinal modes (which travel along the length of the pipe) and transverse modes which couple into the diameter of the pipe. In the latter case, only those wavelengths of sound which are, to a first approximation, less than the diameter of the pipe may be supported. The wavelength of sound, λ, is given by the velocity of sound in the medium, v, divided by the frequency, f. Hence, a pipe of diameter, d, will support all frequencies where $f > v / t$. The velocity of sound in pipe materials is approximately 3000 m/s. (but approximately half this value for plastic). Thus, for a 20 mm. copper pipe the frequencies of relevance to transverse transmission modes will be above 150KHz. Although such frequencies may be generated routinely by some of the physical mechanisms associated with leaks, they are more likely to be indicative of pre-breakdown material stresses. The attenuation of sounds is extremely frequency dependent (typically as the square of frequency). Thus, these high frequeny emissions may travel only a matter of centimetres away from the point at which they originated before they are coupled into the pipe core or exterior where they will be quickly lost.

For longitudinal mode transmission, the relevant physical parameter is the length of pipe between, for example, the outside stop-cock (or the water meter) and the internal stop-cock or point where a T-junction or other device impedes the flow. This is likely to be a distance of, at least, 10 metres and, in the case of a rural property (such as a farm) several hundred metres. Taking a length of 100 metres as an upper bound, then this would support a wavelength of this distance or, putting it another way, a frequency of 30Hz. which is very similar to the lower frequency of hearing. Higher frequencies will also be supported up to a level where interference with transverse modes may be expected i.e. $f > 100$KHz.

In practice, we may only be interested in frequencies in the range 100Hz. to about 40KHz. This is because end reflections may cause interference at the lowest frequencies (unless the source of sound was at the centre of the pipe length) while the higher frequencies suffer attenuation such that their detection at a distance from the source becomes impractical. Thus, the detection system should have a range of 100Hz. to 40,000Hz. Generally, leaks which have not been manifest by an obvious water presence within the house may be assumed to be some 5 metres away from the internal stop-cock and, in most cases, buried under some 50 centimetres of soil.

Transducers for the detection of sound and vibration in a longitudinal mode may be based on the piezoelectric effect which involves the generation of a voltage when stresses are experienced by a natural crystal such as quartz or by a ferroelectric ceramic such as barium titanate or lead ziconate titanate (PZT). In their resonant mode, these crystals can exhibit outstanding sensitivity. However, their rigidity implies a high Q and, subsequently, considerably non-linear behaviour away from resonance.

In the present application, we employ a ceramic piezoelectric element in a monomorph (or unimorph) arrangement in which the thin ceramic disc is bonded to the surface of a thin metal plate. When the circumference of the plate is fixed, then movements of the plate excite strain across the diameter of the piezoelectric crystal which produces a large voltage response. In this case, mechanical resonance occurs when standing waves are set up across this plate. These tend to be in the acoustic range for devices in the order of 10 to 20 mm. diameter and are a function of the plate (Young's modulus, diameter and thickness) rather than the properties of the crystal. By placing the crystal off-centre and by making the plate elliptical and with a radially-dependent thickness, the resonance can be flattened out. Consequently, the device may exhibit high senstivity over a bandwidth of more than 5 octaves.

In the arrangement shown in Figure 1, the monomorph, labelled 3, is coupled to the clip through a short stub, labelled 4, so that the device is angled to form an asymmetric sounding box. This serves to provide mechanical amplification of the sounds detected as well as to provide further non-linearity in the frequency response by destroying the symmetry that produces resonant behaviour. The arrangement is enclosed in a metal pipe labelled 5 which provides structural strength and support whilst also providing electromagnetic screening from the environment and acoustic screening from external sounds. Within the pipe labelled 5 is a PCB

labelled 6 on which are mounted the electronic components that are used to process and amplify the detected signals and to give out the appropriate sign when a leak has been detected.

The electronic circuit on the PCB consists of a high-gain amplifier, a filter arrangement and an output warning device which is activated when the detected signal exceeds a certain threshold. In principle, the filter window may be adjustable in order to allow the device to tune into any particular sounds that are being generated by or transmitted through the pipe. However, our experience has shown that when a measuring device with a relatively flat bandwidth is employed, the signals detected at a range of 5 metres may have a wide bandwidth with components from 100 Hz. up to 20,000 Hz. Consequently, the filter window can be fixed.

It has also been found that the amplitude of the acoustic emissions produced by leaks in a pipe falls quickly with frequency as a function of distance. Thus, a bandpass filter can be used in which the gain of the amplifier increases with increasing frequency and, therefore, cancels out the attenuation function of the sounds. The end result is a device which detects acoustic emissions with a high level of fidelity. It is then a simple task to integrate the sound level and to demonstrate whether the sounds obtained from a pipe are high enough to imply a leak.

A warning indication may be provided to the user using one of a number of different techniques though the preferred system might use a simple LED to indicate a leak. More complex systems may utilise radio telemetry to transmit the message from the sensor and through to a separate display unit. Finally, the output may be fed directly to a sounder device which would indicate a leak if the intensity exceeded a certain value. However, this approach, though useful when access to the pipework is poor, can add signals to the total sound register. The sound produced on a feedback basis can indicate the size of leak because larger leaks produce lower frequency acoustic emissions.

In operation, the water would be switched off at the internal stop-cock (or by closing all taps in the house). The device would then be attached to the incoming pipe at a convenient point in the house, normally within 5 metres of where it enters the house. With as many sources of acoustic interference as possible switched off (radios, TVs etc.), the device would measure the level of propagated sound. If a certain threshold was exceeded (on an integrated frequency basis) then this would be offered as a leak condition.

Claims

1. A new and simplified method of detecting a water leak between the internal stop-cock and the external stop-cock or water meter based on the sensitive detection of acoustic emissions in the frequency range 100Hz to 40,000Hz.
2. A method as described in 1. in which the detection of the acoustic emissions is performed using a piezoelectric monomorph sensor.
3. A method as described in 1. in which the monomorph sensor is coupled to the pipe using a metal clip and an asymmetric sounding box.
4. A method as described in 1. in which the frequence response of the monomorph device is extended by using an eliptical metal plate.
5. A method as described in 1. in which the frequency response of the monomorph device is extended by varying the thickness of the backing plate as a function of radius.
6. A method as described in 1. in which the electronic amplification is performed with a high pass filter circuit which increases the gain as a function of frequency.
7. A method as described in 1. in which the overall sensitivity provides compensation for the frequency dependence of the attenuation of the acoustic emissions along the length of pipe.
8. A method as described in 1. in which a leak condition may be displayed using an optical display such as a light emitting diode.
9. A method as described in 1. which is not dependent on the pressure in the water main.
10. A method as described in 1. in which the size of a leak or its relative position may be determined from the amplitude of signal.
11. A method as described in 1. which may be used with plastic pipes by altering the frequency and gain characteristics of the electronic processing circuitry.
12. A method as described in 1. which rejects emissions produced up-stream due to the asymmetric construction of the acoustic sounding box.

Amendments to the claims have been filed as follows

Claims

1. A new and simplified method of detecting a water leak between the internal stop-cock and the external stop-cock or water meter based on the sensitive detection of acoustic emissions in the frequency range 100Hz to 40,000Hz. utilising

   a piezoelectric monomorph in an eliptical form attached to an asymmetric sounding box and attached directly but in a non-permanent manner to a pipe under test using a metal clip shaped in such a way that it can be pushed onto and released from the pipe with ease,

   a signal processing unit which provides a frequency-dependent gain in order to compensate for the increasing attenuation of sound with increasing frequency,

   a means of comparing the integrated sounds detected with a level detected in the absence of a flow, and

   a visual means of indicating a leak.
2. A method as described in 1. in which the frequence response of the monomorph device may be extended and flattened by using an eliptical metal plate with the ceramic element placed in a non-central position.
3. A method as described in 1. in which the frequency response of the monomorph device is extended by varying the thickness of the backing plate as a function of radius.
4. A method as described in 1. in which the electronic amplification and signal processing is performed with a high pass filter circuit which increases the gain as a function of frequency.
5. A method as described in 1. in which the overall sensitivity provides compensation for the frequency dependence of the attenuation of the acoustic emissions along the length of pipe.
6. A method as described in 1. in which a leak condition may be displayed using an optical display such as a light emitting diode.
7. A method as described in 1. which is not dependent on the pressure in the water main.
8. A method as described in 1. which may be used with plastic pipes by altering the frequency and gain characteristics of the electronic processing circuitry.
9. A method as described in 1. which rejects emissions produced up-stream due to the asymmetric construction of the acoustic sounding box.

The Patent Office

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Examiner:	David Summerhayes
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Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.P): G1G (GPCA)

Int Cl (Ed.6): G01M 3/24

Other:

Documents considered to be relevant:

Category	Identity of document and relevant passage		Relevant to claims
X	GB 2062864 A	(US ENERGY DEPT)	1 at least
X	EP 0451649 A2	(EARL RUBLE)	1 at least
X	EP 0300460 A1	(TOSHIBA)	1 at least
X	EP 0091087 A1	(HITACHI)	1 at least
X	US 4736763	(BRITTON)	1 at least
X	US 4309576	(CORRIGAN)	1 at least

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.